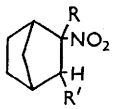
242. *Ring Enlargement during the Reduction of Nitrocycloalkanes by Lithium Aluminium Hydride.*

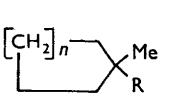
By H. J. Barber and E. Lunt.

Simple tertiary nitrocycloalkanes (II; R = NO_2, n = 1—3) on reduction with lithium aluminium hydride give, in addition to the expected tertiary cycloalkylamines (II; R = NH_2), moderate yields of α-substituted polymethyleneimines (III; n = 1—3) arising from a ring enlargement analogous to that observed previously with bicyclic nitro-compounds of type (I). In one case an additional *N*-substituted rearrangement product was observed. Substantial quantities of the corresponding hydroxylamines (II; R = NH·OH) were also isolated. As the same rearrangement takes place on reduction of these hydroxylamines by lithium aluminium hydride it is believed that the hydroxylamine stage is involved in the rearrangement. Secondary nitrocycloalkanes under the same conditions show much less tendency to rearrange in this way.

This investigation was carried out in order to study, in simpler systems, a novel ring enlargement which takes place [1] during reduction of bridged nitrocycloalkanes of type (I; R = Me or Et, R′ = H or Me) by lithium aluminium hydride. These reductions had given products in high yield which were secondary amines, isomeric with the primary amines expected.



(I)



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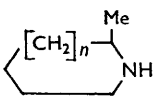

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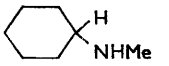


(IV)

In preliminary experiments,[2] reduction of 1-methyl-1-nitrocyclopentane (II; n = 1, R = NO_2) with lithium aluminium hydride resulted in an analogous ring enlargement, giving a secondary amine in yields up to 40%, which was identified as 2-methylpiperidine (III; n = 1). In the reduction of this unbridged compound, however, some 10% of the normal reduction product (II; n = 1, R = NH_2) was also isolated. Reduction of tertiary

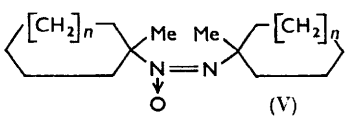
[1] Lee, Wragg, Corne, Edge, and Reading, *Nature*, 1958, **181**, 1717.
[2] Lee, Lunt, Wragg, and Barber, *Chem. and Ind.*, 1958, 417.

nitrocycloalkanes by other methods, such as tin and hydrochloric acid,[3] sodium and alcohol,[4] or catalytic hydrogenation [1] (see also p. 1190) is known to give only the expected primary amine.

This study has now been extended to the larger ring homologues, 1-methyl-1-nitrocyclohexane and -cycloheptane (II; $n = 2$ and 3, R = NO_2). The former gave, in addition to ~15% of the primary base (II; $n = 2$, R = NH_2), a mixture (*ca.* 20% yield) of approximately equal amounts of two isomeric secondary amines $C_7H_{15}N$, which could not be separated by distillation or by crystallisation of derivatives. They were separated, however, by vapour phase chromatography, and the two components were identified, one as the ring-enlarged product, 2-methylhexamethyleneimine (III; $n = 2$), the other as *N*-methylcyclohexylamine (IV). The reason for the formation of the latter product from 1-methyl-1-nitrocyclohexane is not fully understood, but it may be that the greater difficulty of formation of the seven-membered hexamethyleneimine ring causes larger amounts to take an alternative rearrangement path (in which the methyl group migrates to the nitrogen atom).

The primary basic fraction contained, in addition to the cyclohexylamine (II; $n = 2$, R = NH_2), higher-boiling components from which the corresponding hydroxylamine (II; $n = 2$, R = NH·OH) was isolated in 25% yield. Reduction of this hydroxylamine by lithium aluminium hydride gave the same mixture of bases as was obtained from the parent nitro-compound (II; $n = 2$, R = NO_2), together with a high-boiling compound, $C_{14}H_{26}ON_2$, which was also a product of spontaneous decomposition of the hydroxylamine in air. This is believed to be the 1,1′-dimethylazoxycyclohexane (V; $n = 1$) formed from unchanged hydroxylamine during working-up.

1-Methyl-1-nitrocycloheptane (II; $n = 3$, R = NO_2) gave an even lower yield of one secondary amine only, shown to be the ring-enlarged product 2-methylheptamethyleneimine (III; $n = 3$), in addition to a substantial yield of the expected primary amine (II; $n = 3$, R = NH_2). In this case, the only product isolated from the higher-boiling primary basic fraction was the dimethylazoxycycloheptane (V; $n = 2$), the hydroxylamine being even more labile in this case. Similar high-boiling fractions had also been encountered with 1-methyl-1-nitrocyclopentane but were not thoroughly investigated.



(V)

This formation of azoxy-compounds on oxidative decomposition of *N*-(tertiary cycloalkyl)hydroxylamines, paralleling the behaviour of aromatic hydroxylamines, is in marked contrast to the results obtained by Johnson *et al.*[5] with aliphatic hydroxylamines containing free α-hydrogen atoms.

The foregoing reductions of tertiary nitrocycloalkanes also gave non-basic fractions which contained, in addition to recovered nitro-compound, varying amounts of the cycloalkanols (II; R = OH) the origin of which is not known.

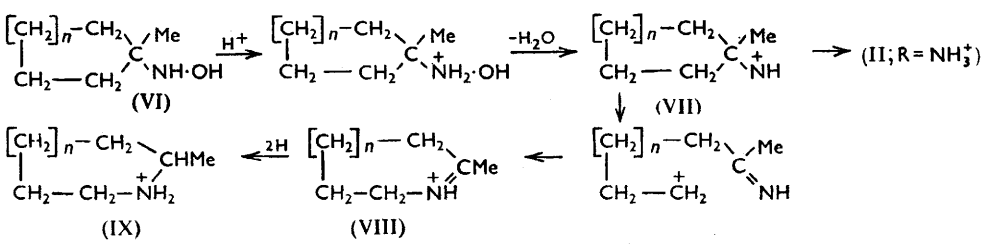
In contrast to the foregoing tertiary nitrocycloalkanes, secondary nitrocycloalkanes showed much less tendency to rearrange on reduction with lithium aluminium hydride. Nitrocyclopentane gave only a low yield of piperidine, in addition to substantial amounts of cyclopentylamine, while nitrocyclohexane gave only a trace of hexamethyleneimine, detected by vapour-phase chromatography. 9-Aci-nitrofluorene gave no phenanthridine-type rearrangement product, the secondary fraction yielding only a small amount of an unidentified base (picrate, m. p. 264—266°). The main product, in addition to 9-aminofluorene, was fluorenone which probably arose from hydrolysis of fluorenone oxime. Small amounts of 9,9′-dinitro-9,9′-bifluorenyl and 9,9′-bifluorenyl itself were also isolated from the non-basic fraction.

Throughout the present work the yields of secondary bases varied from 0 to 40% and

[3] Markownikow and Konowalow, *Ber.*, 1895, **28**, 1234.
[4] Hückel and Nerdel, *Annalen*, 1937, **528**, 57.
[5] Johnson, Rogers, and Trappe, *J.*, 1956, 1093.

were normally higher when reduction was carried out by addition of the lithium aluminium hydride to the nitro-compound than when the more usual procedure was used. Indeed, in the case of the secondary nitrocyclopentane, rearranged product was isolated only when the reverse addition procedure was used.

Since (*a*) considerable quantities of hydroxylamines or their decomposition products are present in the reduction products and (*b*) rearrangement occurs on reduction of 1-methylcyclohexylhydroxylamine to give the same products as are obtained from the parent nitro-compound, it is believed that the hydroxylamine stage is involved in the ring enlargement.



A possible path involves protonation of the hydroxylamine (VI) under the influence of lithium aluminium hydride acting as a Lewis acid (cf. refs. 6, 7), followed by loss of water to give an intermediate (VII) which can be stabilised either by reduction to the primary amine or by rearrangement to the unsaturated base (VIII). Simple reduction of the latter would give the observed saturated derivatives (IX). This must necessarily be an over-simplification, since in a lithium aluminium hydride reaction mixture the various intermediate reduction products are believed [8] to exist, not *per se*, but as complex negative ions of the types $(LiAlRH_2)^-$, $(LiAlR_2H)^-$, and $(LiAlR_3)^-$. A further possibility is that the mechanism could involve an internal rearrangement of a co-ordinated bicyclic complex ion corresponding to the hydroxylamine reduction stage, but many further experimental data are needed before a firm conclusion can be reached.

The nitro-compounds used in this investigation, of which only 1-methyl-1-nitrocycloheptane (III; $n = 3$, $R = NO_2$) is new, were prepared essentially by known methods. 9-Aci-nitrofluorene could not be prepared from 9-bromofluorene by the method of Kornblum *et al.*,[9] as further reaction gave the 9-fluorenyl ether of 9-aci-nitrofluorene.

The reduction products remaining after separation into non-basic, primary, and non-primary basic fractions were examined and further separated by vapour-phase chromatography and identified by the preparation of derivatives for comparison with authentic samples prepared by known methods.

Experimental

1-*Methylcycloalkanols*.—1-Methylcyclopentanol, b. p. 57—60°/26 mm., m. p. 32—33° (Brown and Borkowski [10] give m. p. 32—34°), 1-methylcyclohexanol, b. p. 64—68°/20 mm., n_D^{31} 1·4558 (Brown and Borkowski [10] give b. p. 72—73·5°/29 mm.), and 1-methylcycloheptanol, b. p. 78—82°/16 mm., n_D^{31} 1·4667 (Brown and Borkowski [10] give b. p. 82—83·5°/20 mm., n_D^{20} 1·4690), were obtained in the usual way from the available ketones and methylmagnesium iodide in ether.

1-*Methylcyclopentylamine*.—(a) *From* 1-*methylcyclopentanol* (*Ritter reaction*). 1-Methylcyclopentanol (75 g.) reacted with 96% sodium cyanide (38·2 g.) and sulphuric acid (140 g.) as described for t-butyl alcohol by Ritter and Kalish [11] (cf. Jacquier and Christol [12]). After the

[6] Hunger and Reichstein, *Chem. Ber.*, 1952, **85**, 635.
[7] Edwards and Marion, *Canad. J. Chem.*, 1952, **30**, 627.
[8] Gaylord, "Reduction with Complex Metal Hydrides," Interscience Ltd., London, 1956, pp. 86 *et seq.*
[9] Kornblum, Larson, Blackwood, Mooberry, Olivetti, and Graham, *J. Amer. Chem. Soc.*, 1956, **78**, 1497.
[10] Brown and Borkowski, *J. Amer. Chem. Soc.*, 1952, **74**, 1894.
[11] Ritter and Kalish, *J. Amer. Chem. Soc.*, 1948, **70**, 4048.
[12] Jacquier and Christol, *Bull. Soc. chim. France*, 1957, 596, 600.

mixture had been kept at room temperature overnight, water (280 ml.) was added, followed by sodium hydroxide (360 g.) in water (700 ml.). The mixture was refluxed for 4 hr., then steam-distilled until the distillate (approx. 1400 ml.) was only faintly alkaline. The distillate was acidified with concentrated hydrochloric acid. Some non-basic oil was removed by ether-extraction, and the aqueous layer was basified with sodium hydroxide solution (50% w/w; 200 ml.) and extracted with ether (4 × 200 ml.). The combined ether extracts were dried (Na_2SO_4), the ether removed through a 9″ column from a water-bath, and the residue distilled at atmospheric pressure. The 1-methylcyclopentylamine was collected at 114—117°/757 mm. (36·4 g., 49%; n_D^{20} 1·4454; Markownikow [13] gave b. p. 114°/753 mm., n_D^{25} 1·4408).

From the combined ether distillate and forerun, treatment with ethereal hydrogen chloride afforded further amine as the hydrochloride (29·7 g., 29%), m. p. 266—268° (decomp.). The hydrochloride prepared from the pure amine with ethereal hydrogen chloride crystallised from ethanol–ether in needles, m. p. 270—271° (decomp.) (Hamlin and Freifelder [14] give m. p. 263°) (Found: C, 53·4; H, 10·0; N, 10·5; Cl, 26·25. Calc. for $C_6H_{13}N,HCl$: C, 53·15; H, 10·4; N, 10·3; Cl, 26·15%). The derived *p-chlorophenylthiourea*, m. p. 164—165°, crystallised from ethanol (Found: C, 57·7; H, 6·05; N, 10·5; Cl, 13·3. $C_{13}H_{17}N_2ClS$ requires C, 58·1; H, 6·4; N, 10·4; Cl, 13·2%).

(b) *From 1-methyl-1-nitrocyclopentane.* 1-Methyl-1-nitrocyclopentane (5·2 g.) in ethanol (70 ml.) was hydrogenated at 70 lb. per sq. in. pressure and 26° over Raney nickel catalyst (theoretical hydrogen uptake in 2 hr.). The filtered reaction mixture was treated with ether saturated with hydrogen chloride (60 ml.), and the solvents were removed under reduced pressure at 50°, leaving crude 1-methylcyclopentylamine hydrochloride (5·5 g., 100%), m. p. 266—268° (decomp.). Crystallisation from dry ethanol–ether gave the pure salt (4·2 g., 78%), m. p. 269—270° alone or mixed with a sample prepared from 1-methylcyclopentanol as described above. The infrared spectra of the two samples were identical.

1-Methylcyclohexylamine prepared (76% yield) from the alcohol by method (*a*) above had b. p. 142—146°/759 mm., n_D^{22} 1·4522 (Nametkin [15] gives b. p. 143°/744 mm., n_D^{19} 1·4536) [hydrochloride, m. p. 290—291° (Hamlin and Freifelder [14] give m. p. 285°); *picrate*, m. p. 150—151° (from water) (Found: C, 46·1; H, 5·5; N, 16·35. $C_{13}H_{18}O_7N_4$ requires C, 45·6; H, 5·3; N, 16·35%)]. 1-Methylcycloheptylamine similarly prepared in 78% yield had b. p. 75—79°/25 mm., n_D^{31} 1·4623 (Cope *et al.*[16] give b. p. 82·5°/35 mm., n_D^{25} 1·4644) [picrate, m. p. 169—170° (lit.,[16] 171·6—173°); hydrochloride, m. p. 257—258°]. The derived p-*chlorophenylthiourea*, m. p. 155—156°, crystallised from benzene–light petroleum (b. p. 60—80°) (Found: Cl, 11·6; S, 11·07. $C_{15}H_{21}N_2ClS$ requires Cl, 11·95; S, 10·8%).

1-*Methyl-1-nitrocyclopentane.*—(a) *From methylcyclopentane.* This reaction should be carried out on a small scale (*i.e.*, a few g.) only. The nitro-compound was obtained (1·9 g., 15% yield) from methylcyclopentane and aluminium nitrate nonahydrate as described by Hamlin and Freifelder [14] for the corresponding cyclohexane derivative. It had b. p. 89—92°/37 mm., n_D^{20} 1·4517 (Nametkin [17] gives b. p. 91°/40 mm., n_D^{23} 1·4480). Methylcyclopentane (45%) was recovered from the forerun. The infrared spectrum was essentially the same as that of a sample prepared from 1-methylcyclopentylamine as described below, except for the presence of a trace of a carbonyl constituent (cf. Hamlin and Freifelder [14]).

(b) *From 1-methylcyclopentylamine.* 1-Methylcyclopentylamine (20 g.) was oxidised with potassium permanganate (83 g.) in water (400 ml.) for 24 hr. as described by Kornblum and Clutter,[18] except that the temperature was maintained at 20—25°. (Since the start of this work Kornblum, Clutter, and Jones [19] have obtained improved yields by a modified procedure.) After steam-distillation, finally with addition of 50% aqueous sodium hydroxide (30 ml.), the distillate (approx. 1 l.) was acidified with 2N-hydrochloric acid (100 ml.) and extracted with ether (2 × 150 ml.), and the ether extracts were washed with water and dried. Removal of the ether followed by distillation gave 1-methyl-1-nitrocyclopentane (6·6 g., 25·5%), b. p. 60°/10 mm., n_D^{22} 1·4490. Crude 1-methylcyclopentylamine hydrochloride (10 g., 40%) was recovered from the aqueous layer. (c) *From N-benzylidene-1-methylcyclopentylamine.* The nitro-compound was also

[13] Markownikow, *Annalen*, 1899, **307**, 335.
[14] Hamlin and Freifelder, *J. Amer. Chem. Soc.*, 1953, **75**, 369.
[15] Nametkin, *J. Russ. Phys. Chem. Soc.*, 1910, **42**, 691.
[16] Cope, Bumgardner, and Schweizer, *J. Amer. Chem. Soc.*, 1957, **79**, 4729.
[17] Nametkin, *J. Russ. Phys. Chem. Soc.*, 1911, **43**, 1603.
[18] Kornblum and Clutter, *J. Amer. Chem. Soc.*, 1954, **76**, 4494.
[19] Kornblum, Clutter, and Jones, *J. Amer. Chem. Soc.*, 1956, **78**, 4003.

prepared (47% yield) by a similar permanganate oxidation of *N*-benzylidene-1-methylcyclopentylamine,[14] but much less amine was recovered. The overall yield was little different from that obtained by method (*b*).

1-*Methyl*-1-*nitrocyclohexane*.—This was prepared by method (b) above in 37% yield with 35% recovery of amine. It had b. p. 85—88°/15 mm., n_D^{22} 1·4574 (Nametkin [15] gives b. p. 109—110°/40 mm., n_D^{20} 1·4580). Further experiments showed that the yield of nitro-compound increased with increase in reaction time but there was much lower recovery of amine owing to loss in side-reactions (cf. Kornblum *et al.*[19]). By method (c), *N*-benzylidene-1-methylcyclohexylamine [14] gave a 51% yield of 1-methyl-1-nitrocyclohexane.

1-*Methyl*-1-*nitrocycloheptane* was prepared by method (b) in 23% yield (b. p. 109—113°/18 mm., n_D^{22} 1·4710) with 33% recovery of amine (Found: C, 61·4; H, 9·5; N, 8·3. $C_8H_{15}O_2N$ requires C, 61·1; H, 9·6; N, 8·9%).

9-*Aci-nitrofluorene*.—This compound was obtained by acidification of its potassium salt [20] with ice-cold sulphuric acid. It had m. p. 141—142° (cf. Nenitzescu and Isasescu [21]). An attempted preparation from 9-bromofluorene by treatment with sodium nitrite in dimethylformamide in presence of urea and phloroglucinol [9] (at 20° for 24 hr.) gave 33% of an orange-yellow solid, m. p. 209—210° (decomp.), which was shown to be 9-(*O*-fluorenyl-aci-nitro)fluorene, identical (mixed m. p. and infrared spectrum) with that prepared as described below.

9-(O-*Fluorenyl-aci-nitro*)*fluorene*.—9-Bromofluorene was obtained only in low yield on attempted bromination of fluorene with *N*-bromosuccinimide [22] or 2,4-dibromo-5,5-dimethylhydantoin.[23] It was prepared in quantitative yield (m. p. 102—103°) from 9-fluorenol as described by Hurd and Mold.[24] The bromo-compound (1·35 g.) was refluxed with 9-aci-nitrofluorene potassium salt [20] (1·4 g.) in dry acetone (20 ml.) for 4 hr., cooled, and poured into ice-water (300 ml.). The light brown solid (2·1 g.) thus obtained crystallised from acetic acid (25 ml.) to give 9-(O-*fluorenyl-aci-nitro*)*fluorene* (1·4 g., 67%), m. p. 209—210° (decomp.) (Found: C, 83·0; H, 4·8; N, 3·9. $C_{26}H_{17}O_2N$ requires C, 83·2; H, 4·55; N, 3·75%).

Reaction of Nitro-compounds with Lithium Aluminium Hydride.—(a) 1-*Methyl*-1-*nitrocyclopentane*. Lithium aluminium hydride (13·2 g.) was heated under reflux with dry ether (300 ml.) for 1 hr.; after being cooled the mixture was added dropwise under nitrogen to a stirred solution of 1-methyl-1-nitrocyclopentane (20 g.) in dry ether (300 ml.) so as to maintain gentle refluxing (a procedure referred to as reverse addition). After being stirred at room temperature overnight the mixture was cooled in ice and decomposed by successive cautious addition of water (12·5 ml.), 15% w/v aqueous sodium hydroxide (12·5 ml.), and water (40 ml.). The solid was filtered off and washed well with ether. The combined filtrate and washings were extracted with 2N-hydrochloric acid (150 ml.) and then with water (2 × 100 ml.), and the ether layer was dried and evaporated to yield a non-basic fraction (2·0 g.). Examination of this by vapour-phase chromatography showed presence of unchanged nitro-compound and a little 1-methylcyclopentanol. The acid extracts were basified with aqueous sodium hydroxide and extracted with benzene (4 × 150 ml.). The dried benzene extracts were heated under reflux with benzaldehyde (20 g.) under a Dean and Stark separator until no more water was removed. The benzene solution was cooled in ice and extracted with ice-cold 2N-acetic acid (150 ml.), and then ice-water (4 × 100 ml.). Basification of these extracts and extraction with ether (4 × 200 ml.) gave the non-primary basic fraction, which on removal of ether and distillation gave 2-methylpiperidine, b. p. 118—120°/760 mm. (5·75 g., 37·5%). This base, which was substantially homogeneous on vapour-phase chromatography (same retention time as an authentic sample) and whose infrared spectrum was identical with that of authentic material, was further identified by preparation of the picrate, m. p. 132—133°, *p*-chlorophenylthiourea derivative, m. p. 162—163°, and 3,5-dinitrobenzoyl derivative, m. p. 148—149°. The mixed m. p.s with authentic samples were undepressed.

The crude benzylidene compounds remaining after removal of benzene were hydrolysed by heating with 2N-hydrochloric acid (200 ml.) for 1 hr., then steam-distilled to remove benzaldehyde. The primary basic fraction was isolated by basification and extraction into ether (4 × 200 ml.). Removal of the ether and distillation gave a fraction A (1·6 g., 11%), b. p.

[20] Wislicenus and Waldmuller, *Ber.*, 1908, **41**, 3334.
[21] Nenitzescu and Isasescu, *Ber.*, 1930, **63**, 2484.
[22] Wittig and Felletschin, *Annalen*, 1944, **555**, 133.
[23] Orazi and Mezeri, *Anal. Asoc. quím. argentina*, 1949, **37**, 263.
[24] Hurd and Mold, *J. Org. Chem.*, 1948, **13**, 339.

110—130°/765 mm., which was substantially homogeneous on vapour-phase chromatography, and a higher-boiling fraction B (0·7 g.), b. p. 50—155°/11 mm., which was not further investigated. Fraction A was shown to be 1-methylcyclopentylamine. The hydrochloride, m. p. 269—270° (decomp.), was identical with an authentic sample. The *p*-chlorophenylthiourea derivative was also identical with an authentic sample (m. p. and mixed m. p. 164—165°).

In another experiment 1-methyl-1-nitrocyclopentane (20 g.) was added to lithium aluminium hydride (13·2 g.) in refluxing ether (a procedure referred to as direct addition) and worked up as described above. There were obtained 2-methylpiperidine (4·22 g., 27%) and 1-methylcyclopentylamine (3·06 g., 20%) in addition to the recovered nitro-compound (25%) and a

Nitro-compound	Amount (g.)	Reduction method	Non-basic fraction	Primary basic fraction *	Non-primary basic fraction
1-Methyl-1-nitrocycloheptane	12	Reverse	(14·5%) Not investigated	1-Methylcycloheptylamine (11%) (*a*) + 1,1′-dimethylazoxycycloheptane (10%) (*b*)	2-Methylheptamethyleneimine (6%) (*c*, *d*)
Nitrocyclopentane [9]	12	Direct	Complex mixture (5·5%) (*e*)	Cyclopentylamine (16%) (*f*)	None (*e*)
Nitrocyclopentane [9]	11	Reverse	Complex mixture (4%) (*e*)	Cyclopentylamine (13%) (*f*)	Piperidine (2%) (*e*, *g*)
Nitrocyclohexane (*h*)	20	Reverse	(5%) Not investigated	Cyclohexylamine (18·5%) (*i*) + cyclohexylhydroxylamine (8%) (*j*)	Hexamethyleneimine (trace) (*e*)
9-Aci-nitrofluorene	15	Reverse	22% giving 9,9′-dinitro-9,9′-bifluorenyl (4·5%) (*k*) and 9,9′-bifluorenyl (3%) (*l*)	Fluorenone (27%) (*m*) + 35% mixed bases containing 9-aminofluorene (*n*)	2% Unidentified base as picrate, m. p. 264—266°
1-Methylcyclohexylhydroxylamine	10·5	Reverse	21% Not identified	1-Methylcyclohexylamine (11·5%) (*o*) + 1,1′-dimethylazoxycyclohexane (6%) (*p*)	Mixture of $C_7H_{15}N$ bases (*q*) identical (*e*) with that obtained from 1-methyl-1-nitrocyclohexane

* Some primary amine was generally recovered from the secondary fraction on vapour-phase chromatography owing to the difficulty of achieving complete separation *via* the benzylidene derivatives.

(*a*) Picrate, m. p. and mixed m. p. 167—168°; *p*-chlorophenylthiourea derivative, m. p. and mixed m. p. 155—156°. (*b*) B. p. 180—181°/14 mm., n_D^{22} 1·4973 (Found: C, 71·8; H, 11·0; N, 10·15. $C_{16}H_{30}ON_2$ requires C, 72·1; H, 11·35; N, 10·5%). (*c*) Picrate, m. p. and mixed m. p. 156—157°; *p*-chlorophenylthiourea derivative, m. p. and mixed m. p. 129—131°. (*d*) Isolated by preparative vapour-phase chromatography. (*e*) Analytical vapour-phase chromatography. (*f*) *N*-Benzoyl derivative, m. p. and mixed m. p. 156—157° (lit.,[25] m. p. 157·5—158·5°); *p*-chlorophenylthiourea derivative, m. p. and mixed m. p. 177—178°. (*g*) *p*-Chlorophenylthiourea derivative, m. p. and mixed m. p. 148—149°. (*h*) From Eastman Kodak Co.; single substance on analytical vapour-phase chromatography. (*i*) Hydrochloride, m. p. and mixed m. p. 205—207° (Markownikow [26] gives m. p. 206—207·5°); picrate, m. p. and mixed m. p. 157—158° (Breuer and Schnitzer [27] give m. p. 157—158°); *p*-chlorophenylthiourea derivative, m. p. and mixed m. p. 175—177°. (*j*) M. p. 137—138° (Found: N, 11·95. Calc. for $C_6H_{13}ON$: N, 12·15%) (Vavon and Berton [28] give m. p. 140—141°). (*k*) M. p. 176—177°; mixed m. p. with authentic sample prepared according to Nenitzescu [29] undepressed. (*l*) M. p. 242—244° (Found: C, 93·3; H, 6·1. Calc. for $C_{26}H_{18}$: C, 94·5; H, 5·5%) (Staudinger [30] gives m. p. 239°). (*m*) M. p. 79—81°; mixed m. p. with authentic sample (m. p. 82°) prepared according to Huntress *et al.*[31] 81—82°. (*n*) Hydrochloride, m. p. 215—217°; mixed m. p. with authentic sample (m. p. 217°) prepared as described by Ingold and Wilson [32] was undepressed. (*o*) Hydrochloride, m. p. and mixed m. p. 288—290°; picrate, m. p. and mixed m. p. 149—150°. (*p*) B. p. 153—156°/14 mm., n_D^{21} 1·4894; infrared spectrum identical with that of authentic sample. (*q*) Mixed picrates, m. p. 127—143° (Found: C, 45·75; H, 5·4; N, 16·3. Calc. for $C_7H_{15}N,C_6H_3O_7N_3$: C, 45·6; H, 5·3; N, 16·35%).

[25] Markownikow and Kaschirin, *Ber.*, 1897, **30**, 974.
[26] Markownikow, *Annalen*, 1898, **302**, 1.
[27] Breuer and Schnitzer, *Monatsh.*, 1936, **68**, 301.
[28] Vavon and Berton, *Bull. Soc. chim. France*, 1925, **37**, 296.
[29] Nenitzescu, *Ber.*, 1929, **62**, 2669.
[30] Staudinger, *Ber.*, 1906, **39**, 3060.
[31] Huntress, Hershberg, and Cliff, *J. Amer. Chem. Soc.*, 1931, **53**, 2720.
[32] Ingold and Wilson, *J.*, 1933, 1493.

higher-boiling hydroxylamine fraction, b. p. 110—125°/10 mm. (5·5%), corresponding to B above.

(b) 1-*Methyl*-1-*nitrocyclohexane*. 1-Methyl-1-nitrocyclohexane (20 g.) was reduced (reverse addition) and the products were separated as described above to give non-basic, primary basic, and non-primary basic fractions. The non-basic fraction (6·5%) consisted largely of 1-methylcyclohexanol (infrared spectrum identical with that of authentic material; 3,5-dinitrobenzoate, m. p. and mixed m. p. 130—132°). The primary basic fraction gave 1-methylcyclohexylamine (14%) (hydrochloride, m. p. and mixed m. p. 291—292°; correct infrared spectrum) and *N*-(1-methylcyclohexyl)hydroxylamine (12%), b. p. 136—141°/47 mm. The non-primary basic fraction (3·28 g., 21%) was shown by vapour-phase chromatography on an Apiezon-L–Celite column at 132° to consist of a little 1-methylcyclohexylamine (picrate, m. p. and mixed m. p. 149—150°), formed by slight hydrolysis of the benzylidene derivative, and a mixture of isomeric $C_7H_{15}N$ secondary bases [mixed picrates, m. p. 127—143° (Found: C, 45·85; H, 5·49; N, 16·7. Calc. for $C_7H_{15}N,C_6H_3O_7N_3$: C, 45·6; H, 5·3; N, 16·35%)] which could not be separated by crystallisation of derivatives.

Direct-addition reduction gave essentially the same mixture. 1-Methyl-1-nitrocyclohexane (20 g.) gave 1-methylcyclohexylamine (6·5%), N-(1-*methylcyclohexyl*)*hydroxylamine* (3·9 g., 22%), m. p. 73—75° raised to 74—75° by crystallisation from light petroleum (b. p. 40—60°) (Found: C, 65·05; H, 11·55; N, 11·1. $C_7H_{15}ON$ requires C, 65·05; H, 11·7; N, 10·85%), and a non-primary basic fraction, which was shown by vapour-phase chromatography to contain the same mixture of bases as was obtained on reverse addition reduction, but in smaller amount.

In a further large-scale (78 g.) reduction by the reverse addition method the benzaldehyde separation was therefore omitted and the total basic fraction isolated. Distillation gave a basic fraction (25·7 g., 42%), b. p. 100—160°/756 mm., 75—95°/17 mm., and *N*-(1-methylcyclohexyl)hydroxylamine (17·55 g., 25%), b. p. 111—115°/17 mm. (neutral oxalate, m. p. and mixed m. p. 184—185°).

The lower-boiling basic fraction was separated by preparative vapour-phase chromatography on Apiezon-L–Celite at 132° into 1-methylcyclohexylamine (13·5%) (hydrochloride, m. p. and mixed m. p. 291—292°; picrate, m. p. and mixed m. p. 149—150°) and mixed $C_7H_{15}N$ secondary bases (5·8 g., 9·5%) as before. The latter were separated by further chromatography on a glycerol 1,3-di-*m*-tolyl ether–Celite column at 132° into 2-methylhexamethyleneimine (1·6 g., 2·5%) (correct infrared spectrum) (picrate, m. p. 130—131°; mixed m. p. with authentic sample 132—133°; hydrochloride, m. p. and mixed m. p. 199—200°; derived *p*-chlorophenylthiourea, m. p. and mixed m. p. 159—160°), and *N*-methylcyclohexylamine (1·4 g., 2·5%) (picrate, m. p. and mixed m. p. 170—171°; hydrochloride, m. p. and mixed m. p. 180—181°, having the correct infrared spectrum).

Other Reductions by Lithium Aluminium Hydride.—Details of other reductions and products obtained are given in the Table.

Preparation and Characterisation of Authentic Samples.—(i) 2-Methylpiperidine (b. p. 118—119°) gave the picrate as thick rods, m. p. 127—128°, from benzene (Marckwald [33] gives m. p. 127—128°), or as fine needles, m. p. 132—133° from water (Lipp [34] gives m. p. 134—135°). The p-*chlorophenylthiourea derivative*, crystallised from benzene, had m. p. 162—163° (Found: C, 58·2; H, 6·2; N, 10·55; Cl, 13·4. $C_{13}H_{17}N_2ClS$ requires C, 58·1; H, 6·4; N, 10·4; Cl, 13·2%). The N-3,5-*dinitrobenzoyl derivative*, m. p. 148—149°, crystallised from ethanol (Found: C, 53·2; H, 5·1; N, 14·1. $C_{13}H_{15}O_5N_3$ requires C, 53·25; H, 5·15; N, 14·3%).

(ii) 2-Methylhexamethyleneimine was prepared from 2-methylcyclohexanone according to Blicke and Doorenbos [35] [picrate, m. p. 133—134° (Gabriel [36] gives m. p. 131°); hydrochloride, m. p. 199—200° (Muller and Krauss [37] give m. p. 200°)]. The p-*chlorophenylthiourea derivative* had m. p. 159—160° (Found: N, 9·71; Cl, 12·75; S, 11·25. $C_{14}H_{19}N_2ClS$ requires N, 9·9; Cl, 12·55; S, 11·35%).

(iii) 2-Methylheptamethyleneimine was similarly prepared from 2-methylsuberone.[38] The intermediate 2-methyl-8-oxoheptamethyleneimine (b. p. 94—98°/0·05 mm.) was reduced directly

[33] Marckwald, *Ber.*, 1896, **29**, 43.
[34] Lipp, *Annalen*, 1896, **289**, 173.
[35] Blicke and Doorenbos, *J. Amer. Chem. Soc.*, 1954, **76**, 2317.
[36] Gabriel, *Ber.*, 1909, **42**, 1259.
[37] Muller and Krauss, *Monatsh.*, 1932, **61**, 212.
[38] Godchot and Cauquil, *Compt. rend.*, 1929, **188**, 794.

without further purification, and the base, b. p. 62—64°/15 mm., was further purified by preparative vapour-phase chromatography (18·5% yield on 2-methylsuberone) (n_D^{20} 1·4665) [*N*-benzenesulphonyl derivative, m. p. 114—115° (Gabriel [39] gives m. p. 114—115°); picrate, m. p. 156—157° (Gabriel [39] gives m. p. 152—153°)]. The *hydrochloride* had m. p. 165—166° (Found: N, 8·67; Cl, 21·8. $C_8H_{17}N$,HCl requires N, 8·55; Cl, 21·65%); the p-*chlorophenylthiourea derivative* had m. p. 130—131° (Found: C, 60·9; H, 7·05; N, 9·3; Cl, 12·1. $C_{15}H_{21}N_2ClS$ requires C, 60·7; H, 7·15; N, 9·45; Cl, 11·95%).

(iv) *N*-Methylcyclohexylamine was prepared as described by Blicke and Lu [40] [hydrochloride, m. p. 180—181°, from acetone (Lukes and Jizba [41] give m. p. 177—178°); picrate, m. p. 170—171° (Skita and Rolfes [42] give m. p. 170°). The p-*chlorophenylthiourea derivative* had m. p. 149—150° (Found: N, 10·2; Cl, 12·6; S, 11·0. $C_{14}H_{19}N_2ClS$ requires N, 9·9; Cl, 12·55; S, 11·35%)].

(v) Piperidine. The p-*chlorophenylthiourea derivative* (prepared from redistilled base, b. p. 106°) had m. p. 150—151° (Found: N, 11·0; Cl, 13·9; S, 12·6. $C_{12}H_{15}N_2ClS$ requires N, 11·0; Cl, 13·9; S, 12·6%).

(vi) Cyclopentylamine was prepared by reductive amination of cyclopentanone as described by Corrigan *et al.*[43] The *hydrochloride* had m. p. 206—207° (Found: C, 49·4; H, 9·95; N, 11·5; Cl, 29·15. $C_5H_{11}N$,HCl requires C, 49·4; H, 9·9; Cl, 29·2%). The p-*chlorophenylthiourea derivative* (from ethanol) had m. p. 179—180° (Found: N, 11·0; Cl, 14·1; S, 12·7. $C_{12}H_{15}N_2ClS$ requires N, 11·0; Cl, 13·9; S, 12·6%). The *picrate* (from dilute acetic acid) had m. p. 136—137° (Found: C, 42·25; H, 4·8; N, 18·0. $C_{11}H_{14}O_7N_4$ requires C, 42·05; H, 4·5; N, 17·85%).

(vii) Cyclohexylamine. The p-*chlorophenylthiourea derivative* had m. p. 176—177° (Found: C, 58·3; H, 6·0; Cl, 13·2; S, 11·7. $C_{13}H_{17}N_2ClS$ requires C, 58·1; H, 6·4; Cl, 13·2; S, 11·95%).

(viii) 1-*Methylcyclohexyl* 3,5-*dinitrobenzoate* crystallised from ethanol as pale yellow plates, m. p. 132—133° (Found: C, 54·45; H, 5·25; N, 9·25. $C_{14}H_{16}O_6N_2$ requires C, 54·55; H, 5·25; N, 9·1%).

N-(1-Methylcyclopentyl)hydroxylamine was prepared in 54% yield (on unrecovered nitro-compound) by reduction of 1-methyl-1-nitrocyclopentane with zinc dust and aqueous ammonium chloride at 70°. It was isolated as the *hydrochloride*, m. p. 148—149° (Found: C, 47·5; H, 9·25; N, 8·85; Cl, 23·3. $C_6H_{13}ON$,HCl requires C, 47·55; H, 9·3; N, 9·25; Cl, 23·4%). Attempts to prepare this or the following compound from the corresponding bromide by Exner's method [44] or by a convenient modification of this method using the alcohol with acetoxime in concentrated hydrobromic acid–acetic acid were unsuccessful.

N-(1-Methylcyclohexyl)hydroxylamine was similarly prepared in 78% yield (on unrecovered nitro-compound), and had m. p. 71—73°. The neutral *oxalate* had m. p. 184—185° (Found: C, 55·2; H, 9·3; N, 7·9. $2C_7H_{15}ON,C_2H_2O_4$ requires C, 55·15; H, 9·25; N, 8·05%). The free base slowly decomposed in air to an orange liquid, which on distillation gave 1,1′-*dimethylazoxycyclohexane* (77%), b. p. 159—162°/17 mm., n_D^{23} 1·4912 (Found: C, 70·55; H, 11·0; N, 12·2. $C_{14}H_{26}ON_2$ requires C, 70·55; H, 11·0; N, 11·75%).

N-(9-*Fluorenyl*)*hydroxylamine*, prepared in low yield (2%) from 9-bromofluorene by Exner's method,[44] had m. p. 124° (from cyclohexane) (Found: C, 79·8; H, 5·8; N, 7·25. $C_{13}H_{11}ON$ requires C, 79·2; H, 5·6; N, 7·1%). Since this work was completed, Wragg and Stevens [45] have described the oxalate of this base, prepared by a similar method in low and variable yield.

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[45] Wragg and Stevens, *J.*, 1959, 461.